Mercury in Water and Sediments in the Churchill and Nelson Rivers, Manitoba, Canada

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Environment and
Workplace Safety
and Health

MERCURY IN WATER AND SEDIMENTS IN THE CHURCHILL AND NELSON RIVERS MANITOBA, CANADA

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SPECIAL NOTE

This report was prepared for the Canada-Manitoba Agreement on the Study and Monitoring of Mercury in the Churchill River Diversion. Any conclusions, recommendations, or opinions expressed herein are those of the author and are not necessarily the same as those of the Steering Committee for this Agreement.

SUMMARY

Concentrations of extractable mercury in water and total mercury in river and lake surficial bottom sediments were measured in samples collected from areas affected by stream regulation projects in the Churchill and Nelson Rivers. The data base extends from approximately 1977 to 1984 for mercury in water and from 1979 to 1983 for mercury in bottom sediments. This data was generated as part of a routine water quality monitoring activity within the Province of Manitoba.

Most extractable mercury in water observations were below the analytical limit of quantitation (0.02 µg/L). The few exceptions were likely either influenced by sampling or analytical bias or were representative of the upper percentiles of the normal distribution of extractable mercury in water within this area.

Total mercury concentrations in surficial bottom sediments displayed little apparent change at all sites throughout the duration of the investigation. Similarly, little difference was apparent between the various sites examined within areas affected by the Churchill River diversion, within areas affected by Lake Winnipeg regulation and at one unaffected site.

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Introduction

Data for a variety of physical and chemical water quality variables within several aquatic media were collected from a wide geographical area within Manitoba. The information generated from this routine water quality monitoring activity supported environmental management programs. Data uses are numerous and include for example, delineation of long-term changes and trends in water quality, characterization of background or ambient water quality or relating observed water quality trends to pollution abatement programs or to environmental interventions.

It was thought that a portion of the data generated by this monitoring activity would add to the information base regarding the presence and distribution of mercury within areas affected by the Churchill River diversion. The collection and assessment of this information, identified as Project 1.1, was not cost-shared under the Canada-Manitoba Agreement on the Study and Monitoring of Mercury in the Churchill River Diversion, since it was part of an ongoing program of the Manitoba Department of Environment and Workplace Safety and Health.

Water quality monitoring activities within northern Manitoba commenced in the early 1970's with joint Canada-Manitoba studies being undertaken under the guidance of the Lake Winnipeg, Churchill and Nelson Rivers Study Board. Subsequent to these early studies, program evolution occurred such that monitoring continued at some original sites, monitoring was discontinued at other sites and monitoring was initiated at further locations. Parametric coverage also changed in accordance with perceived needs and changes in analytical technologies.

While studies under this mercury agreement were specific to areas affected by the Churchill River diversion projects, the information discussed within this report also include data collected from the upper Nelson River. Hence, the entire general geographical area encompassed by the Northern Flood Agreement was included.

Mercury in natural waters can exist as elemental mercury (0), the mercurous form (+1) or as the mercuric state (+2). Mercury speciation is dependent upon pH, redox potential and the characteristics of the anions available for stable bonding (Moore and Ramamoorthy, 1983). The occurrence of mercury in water can result from both natural and anthropogenic sources. Natural sources include mercury-bearing sulfide minerals such as cinnabar, metacinnabar, and sphalerite as well as elemental mercury. Anthropogenic sources include industrial and municipal wastewater including wastes produced from the smelting of ores to extract metals such as lead, zinc and copper (Faust and Aly, 1980).

Both aerobic and anerobic bacteria can methylate divalent inorganic mercury into methyl mercury (National Research Council, 1978). Methylated mercury is more soluble in water and is more biologically active in water than either elemental mercury or divalent inorganic mercury. Consequently, it is the methylated mercury forms that are of most concern within aquatic systems because of their propensity to biomagnify throughout the food chain. Once mercury is incorporated within biological tissues, attenuation is slow.

The measurement of extractable mercury in water within this routine monitoring activity was designed to detect material increases

in the combined inorganic and organic forms of mercury present, should such increases be of sufficient magnitude to cause the routine positive detection of mercury in water. Unfortunately, an alteration of the ratio of inorganic to organic forms of mercury within these aquatic systems, caused by changes in the rate of methylation-demethylation, would not be detected.

Moore and Ramamoorthy (1983) summarized the major environmental processes affecting mercury within suspended and bed sediments. Both sorption and bonding correlated best with the organic content of sediments. Mercury can be associated with sediments to various degrees ranging for example, from weak Van der Waals forces to strong covalent bonding, co-precipitation with iron-manganese nodules and incorporation in crystal lattices. Mercury can also be released from sediments into the interstitial and surficial waters, dependent upon both physical and chemical properties of the sediment and water. Munawar et al. (1984) reported that sediments act as a reservoir for trace metals in aquatic environments. This has been substantiated by numerous investigations. For example, 97% of the mercury within the Ottawa River was associated with bed sediments (Kudo et al. 1977).

Moore and Ramamoorthy (1983) further reported that partitioning between mercury in suspended sediments and mercury in water have been calculated to be approximately 1×10^5 times. Thus, given knowledge of the mercury content of suspended sediments, it is possible to estimate the concentration of dissolved mercury.

Knowledge of the temporal changes of mercury concentrations within bed sediments is a useful tool for monitoring both the

redistribution of mercury within riverine systems and the possible material increase of mercury into any aquatic system from anthropogenic sources such as base-metal mining and smelting operations. However, this information alone may not provide the necessary information for water quality managers to anticipate mercury associated problems with biomagnification through the aquatic food chain. The biological transformation of mercury within bed sediments can occur at rates which are independent of either the redistribution of mercury or the anthropogenic influenced increase of sediment related total mercury. The principal previously mentioned biological-related transformation, namely methylation and demethylation, can readily alter the sediment associated inorganic mercury to the more readily biomagnified organic mercury without substantially altering the total mercury concentration.

Methodology

Analyses for mercury in water at most sites affected by the Churchill River diversion were initiated during the summer of 1977 or during the winter of 1978 and continued until March, 1984. However, sampling was somewhat variable. For example, insecure ice conditions near the community of South Indian Lake precluded the safe collection of samples from ski-equipped aircraft during winter months. Therefore, an alternate location within the South Basin of Southern Indian Lake was chosen. An alternate sampling site at Apussigamasi Lake on the Burntwood River was also used for the same reason.

It should be noted that, while the Barrington River upstream of Opachuanau Lake is geographically located upstream of the point of

diversion, it is nevertheless influenced by water level fluctuations resulting from the operation of the diversion. Further, Footprint Lake is not located directly on the diversion route but is influenced through tributary streams.

Water samples for mercury analyses were collected in triplicate in 100 mL Soveril pyrex glass containers from approximately 0.5 m below the water surface. The Soveril pyrex glass sample containers had previously been subjected to heat at 105°C for 4 to 5 hours in order to ensure that all trace of mercury was removed by vapourization. The samples were immediately preserved with the addition of 1 mL of concentrated nitric acid and 1 mL of 5% potassium dichromate. The samples were cooled with ice, then shipped to the W. M. Ward Technical Services Laboratory in Winnipeg for analyses. Samples were received within twenty-four hours of collection; analyses were completed within fourteen days of collection.

The principle of the analytical method has been described by Sorba et al. 1980: The sample containers were allowed to stand undisturbed for several hours, then an aliquot was decanted for analyses. The organic mercury compounds in the aliquot were oxidized to inorganic mercury by heating with sulphuric acid, potassium permanganate and potassium persulfate at a high temperature within a closed system. Stannous chloride in a hydroxylamine sulphate-sodium chloride solution was added in order to reduce all mercuric compounds to elemental mercury. The elemental mercury was passed through a 30 cm Pharmacia UV photometer. Absorbance was measured at 253.7 nm. Mercury was reported as extractable. The analytical limit of quantitation was 0.02 µg/L, with the exception of August and September, 1977, when the limit was 0.05 µg/L.

Surficial bottom sediment samples were obtained with the use of a standard Wildco Ponar dredge. Sediment sampling was initiated in 1979 and continued until 1983. Samples were collected in triplicate, where possible in 1979, 1980, 1981 and 1983. Single samples only were collected in 1982. The top 1 to 3 cm of sediment were removed, placed in whirl-pac bags, and shipped to the W. M. Ward Technical Services Laboratory in Winnipeg for analyses. Samples were stored frozen until analyses could be completed.

The analysis was carried out in accordance with the method described by Sorba et al. (1980). Inorganic forms of mercury were extracted and organic forms were oxidized in a 1 g (wet weight) sediment aliquot by digestion with sulphuric acid, nitric acid, hydrochloric acid, potassium permanganate and potassium persulphate. The clear supernatant was then analyzed using a similar procedure as described previously for determining extractable mercury concentrations in water. The analytical limit of quantitation was 0.02 µg/g (wet weight). The results were reported as dry weight equivalent total mercury.

Results and Discussion

Mercury in Water

The sampling locations are shown in Figure 1, and are described in Table 1. Extractable mercury data in water are presented in Table 2.

With few exceptions all extractable mercury concentrations in water samples collected from areas affected by the Churchill River diversion, and from one upstream unaffected site were less than the limit of quantitation (0.02 µg/L). The occasional concentrations

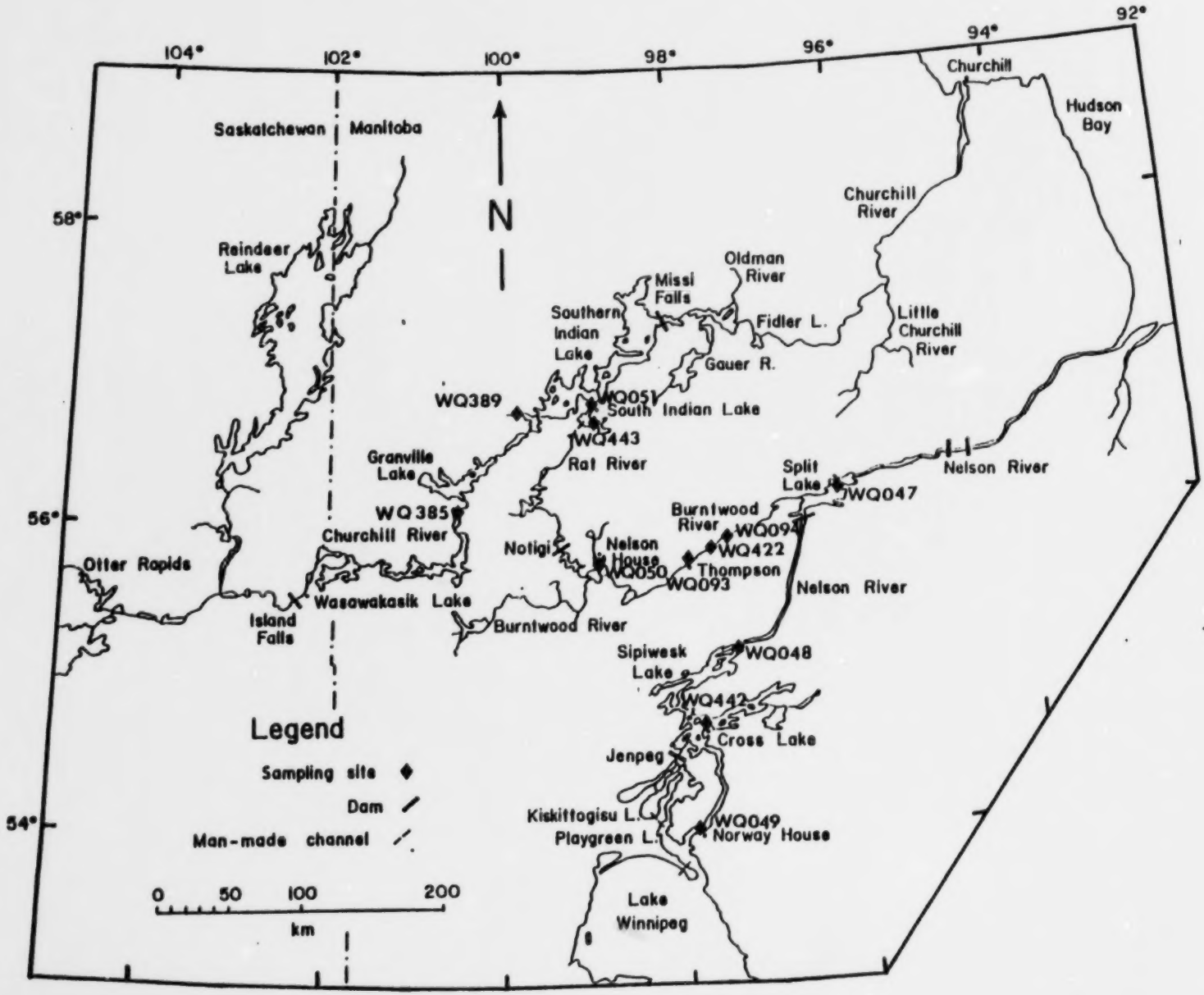

Figure 1: Location of sampling sites.

Table 1: Description of sampling locations.

	<u>Upstream - Churchill River Diversion</u>
WQ 385	Churchill River upstream of Granville Lake. Lat. 56:08; Long. 100:30
	<u>Influenced - Churchill River Diversion</u>
WQ 389	Barrington River upstream of Opachuanau Lake Lat. 56:45; Long. 99:58
WQ 051	Southern Indian Lake near the community of South Indian Lake. Lat. 56:46; Long. 98:57.
WQ 443	Southern Indian Lake near the centre of the South Bay. Lat. 56:44; Long. 99:00
WQ 050	Footprint Lake near the community of Nelson House. Lat. 55:46; Long. 98:54
WQ 093	Burntwood River at Thompson Lat. 55:45; Long. 97:50
WQ 422	Burntwood River at Apussigamasi Lake, inlet area. Lat. 55:49; Long. 97:42
WQ 094	Burntwood River at Apussigamasi Lake, central area. Lat. 55:51; Long. 97:36
WQ 047	Split Lake near the community of Split Lake. Lat. 56:14; Long. 96:05
	<u>Upper Nelson River</u>
WQ 049	Little Playgreen Lake near the community of Norway House. Lat. 53:59; Long. 97:50
WQ 442	Cross Lake near the community of Cross Lake. Lat. 54:37; Long. 97:47
WQ 048	Sipiwesk Lake, near outlet Lat. 55:13; Long. 97:20

Table 2: Extractable mercury concentrations in surface waters within the study area.

WQ 385 Churchill River up-stream of Granville Lake		WQ 389 Barrington River up-stream of Opachuanau Lake		WQ 051 Southern Indian Lake near the Community of South Indian Lake		WQ 443 Southern Indian Lake near the Centre of South Bay		WQ 050 Footprint Lake Near the Community of Nelson House		WQ 093 Burntwood River at Thompson	
Date	µg(Hg/L	Date	µg(Hg)/L	Date	µg(Hg)/L	Date	µg(Hg)/L	Date	µg(Hg)/L	Date	µg(Hg)/L
78 02 09	0.02 L*	78 02 09	0.02 L	77 06 07	0.02	78 02 07	0.02 L	77 06 07	0.03 L	77 08 16	0.05 L
78 03 09	0.02 L	78 03 09	0.02 L	77 07 18	0.02 L	78 03 09	0.02 L	77 07 18	0.02 L	77 09 13	0.05 L
78 06 07	0.02 L	78 06 07	0.02 L	77 08 16	0.05 L	79 01 08	0.02 L	77 09 13	0.05 L	77 10 19	0.04
78 07 10	0.02 L	78 07 10	0.02 L	77 09 13	0.05 L	79 02 05	0.02 L	78 02 09	0.02 L	78 02 08	0.02 L
78 08 17	0.02 L	78 08 17	0.02 L	78 06 07	0.02 L	79 03 05	0.02 L	78 03 09	0.02 L	78 03 08	0.02 L
78 09 11	0.02	78 09 11	0.02	78 07 10	0.02 L	80 01 07	0.02 L	78 06 07	0.02 L	78 06 06	0.02 L
78 10 18	0.02 L	78 10 18	0.02 L	78 08 17	0.02 L	80 02 11	0.02 L	78 07 10	0.02 L	78 07 10	0.02 L
79 01 08	0.02 L	79 01 08	0.02 L	78 09 11	0.02	80 03 11	0.02 L	78 08 16	0.02 L	78 08 16	0.02 L
79 02 05	0.02 L	79 02 05	0.02 L	78 10 18	0.02 L	81 01 20	0.02 L	78 09 11	0.02	78 09 12	0.02
79 03 05	0.02 L	79 03 05	0.02 L	79 06 12	0.02 L	81 03 18	0.02 L	78 10 18	0.02 L	78 10 17	0.02 L
79 06 12	0.02 L	79 06 12	0.02 L	79 07 09	0.02 L	82 01 13	0.02 L	79 01 08	0.02 L	79 01 10	0.02 L
79 08 13	0.02 L	79 07 09	0.02 L	79 08 13	0.02 L	82 02 10	0.02 L	79 02 05	0.02 L	79 02 07	0.02 L
79 09 10	0.02 L	79 08 13	0.02 L	79 09 10	0.02 L	84 03 07	0.02 L	79 03 05	0.02 L	79 03 05	0.02 L
79 10 16	0.02 L	79 09 10	0.02 L	79 10 15	0.02 L			79 06 12	0.02 L	79 06 12	0.02 L
80 01 08	0.02 L	79 10 16	0.02 L	80 06 09	0.02 L			79 07 10	0.02 L	79 07 10	0.02
80 02 12	0.02 L	80 01 08	0.02 L	80 07 07	0.02 L			79 08 13	0.02 L	79 08 15	0.02 L
80 03 11	0.02 L	80 02 12	0.02 L	80 08 11	0.02 L			79 09 10	0.02 L	79 09 10	0.02 L
80 06 09	0.02 L	80 03 11	0.02 L	80 09 09	0.02 L			79 10 15	0.02 L	79 10 17	0.02 L
80 07 07	0.02 L	80 06 09	0.02 L	81 06 01	0.02 L			80 01 08	0.02 L	80 01 09	0.02 L
80 08 11	0.02	80 07 07	0.02 L	81 07 27	0.02 L			80 02 12	0.02 L	80 02 11	0.02 L
80 09 09	0.02 L	80 08 11	0.02 L	81 10 07	0.02 L			80 03 10	0.02 L	80 03 13	0.02 L
81 01 20	0.02 L	80 09 09	0.02	82 06 10	0.02 L			80 06 09	0.02 L	80 06 09	0.02 L
81 06 01	0.02 L	81 01 20	0.02 L	82 07 06	0.02 L			80 07 07	0.02 L	80 07 07	0.02 L
81 07 27	0.02 L	81 03 18	0.02 L	82 08 18	0.02 L			80 08 11	0.02 L	80 08 11	0.02 L
81 10 07	0.02 L	81 06 01	0.02 L	83 07 06	0.02 L			80 09 09	0.02	80 09 11	0.02 L
82 01 13	0.02 L	81 07 27	0.02 L	83 08 24	0.02 L			81 01 20	0.02 L	81 01 20	0.02 L
82 02 10	0.02 L	81 10 07	0.02 L	84 02 06	0.02 L			81 02 19	0.02 L	81 02 19	0.02 L
82 06 10	0.02 L	82 01 13	0.02 L					81 03 18	0.02 L	81 03 17	0.02 L
82 07 06	0.02 L	82 02 10	0.02 L					81 06 01	0.02 L	81 06 01	0.02 L
82 08 18	0.02 L	82 06 10	0.02 L					81 07 27	0.02 L	81 07 27	0.02 L
83 07 06	0.02 L	82 07 06	0.02 L					81 10 07	0.02 L	81 10 06	0.02 L
83 08 24	0.02 L	82 08 18	0.02 L					82 01 13	0.02 L	82 01 12	0.02 L
83 09 20	0.02 L	83 07 06	0.02 L					82 02 10	0.02 L	82 03 10	0.02 L
84 01 09	0.02 L	83 08 24	0.02 L					82 06 10	0.02 L	82 06 09	0.02 L
84 03 07	0.02 L	83 09 20	0.02 L					82 07 06	0.02 L	82 07 08	0.02 L
		84 02 06	0.02 L					82 08 18	0.02 L	82 07 08	0.02 L
		84 03 07	0.02 L					83 07 06	0.02 L	82 08 17	0.02 L
								83 08 24	0.02 L	83 07 05	0.02 L
								83 09 20	0.02 L	83 08 23	0.02 L
								84 01 09	0.02 L	83 09 19	0.02 L
								84 02 06	0.02 L	84 01 11	0.02 L
								84 03 07	0.02 L	84 02 06	0.02 L
										84 03 06	0.02 L

* Values qualified by a "L" were less than the technical limit of quantitation.

Table 2: continued

WQ 422 Burntwood River at Apussigamasi Lake, Inlet Area		WQ 094 Burntwood River at Apussigamasi Lake, Central Area		WQ 047 Split Lake near the Community of Split Lake		WQ 049 Little Playgreen Lake near the Community of Norway House		WQ 442 Cross Lake near the Community of Cross Lake		WQ 048 Sipiwesk Lake near Outlet Area	
Date	µg(Hg)/L	Date	µg(Hg)/L	Date	µg(Hg)/L	Date	µg(Hg)/L	Date	µg(Hg)/L	Date	µg(Hg)/L
79 06 12	0.02 L			77 06 08	0.02 L	77 06 06	0.02 L	78 02 06	0.02 L	77 06 06	0.07 L
79 07 10	0.02 L	77 08 15	0.05 L	77 07 18	0.02 L	77 07 19	0.03	78 03 07	0.02 L	77 07 19	0.03
79 08 13	0.02 L	77 09 13	0.05 L	77 08 15	0.05 L	77 08 17	0.05 L	78 06 05	0.02 L	77 08 17	0.05 L
79 09 10	0.02 L	77 10 19	0.02 L	77 09 13	0.05 L	77 09 12	0.05 L	78 07 13	0.02 L	77 09 12	0.05 L
79 10 17	0.02 L	78 02 06	0.02 L	78 02 08	0.02 L	78 02 06	0.02 L	78 08 15	0.03	78 02 06	0.02 L
80 06 09	0.02 L	78 03 09	0.02 L	78 03 09	0.02 L	78 03 07	0.02 L	78 09 12	0.02 L	78 03 07	0.02 L
80 07 07	0.02 L	78 06 06	0.02 L	78 06 06	0.02 L	78 06 05	0.02 L	78 10 16	0.02 L	78 06 05	0.02 L
80 08 11	0.02 L	78 07 10	0.02 L	78 07 10	0.02	78 07 13	0.02 L	79 01 09	0.02 L	78 07 13	0.02 L
80 09 09	0.02 L	78 08 16	0.02 L	78 08 17	0.02 L	78 08 15	0.03	79 02 07	0.02 L	78 08 15	0.02 L
81 06 04	0.02 L	78 09 12	0.02 L	78 09 11	0.02	78 09 12	0.02	79 06 13	0.02 L	78 09 12	0.02
81 07 28	0.02 L	78 10 18	0.02 L	79 01 10	0.02 L	78 10 16	0.02 L	79 07 10	0.02 L	78 10 16	0.02 L
81 10 07	0.02 L	79 01 10	0.02 L	79 02 07	0.02 L	79 01 09	0.02 L	79 08 14	0.02 L	79 01 09	0.02 L
82 06 09	0.02 L	79 02 07	0.02 L	79 03 05	0.02 L	79 02 07	0.02 L	79 10 17	0.02 L	79 02 07	0.02 L
82 07 06	0.02 L	79 03 05	0.02 L	79 06 12	0.02 L	79 03 06	0.02 L	80 01 09	0.02 L	79 03 06	0.02 L
82 08 17	0.02 L	80 01 09	0.02 L	79 08 13	0.02 L	79 06 13	0.02 L	80 02 14	0.02 L	79 06 13	0.02 L
83 07 05	0.02 L	80 02 11	0.02 L	79 09 10	0.02 L	79 07 10	0.02 L	80 03 13	0.02 L	79 07 10	0.02 L
83 08 23	0.02 L	80 03 10	0.02 L	79 10 15	0.02 L	79 08 14	0.02 L	80 06 10	0.02 L	79 08 14	0.02 L
83 09 19	0.02 L	81 01 20	0.02 L	80 01 07	0.02 L	79 10 17	0.02 L	80 07 08	0.02 L	79 10 15	0.02 L
		81 03 18	0.02 L	80 02 11	0.02 L	80 01 09	0.02 L	80 08 13	0.02 L	80 01 09	0.02 L
				80 03 10	0.02 L	80 02 14	0.02 L	80 09 10	0.02 L	80 02 14	0.02 L
				80 06 09	0.02 L	80 03 13	0.04	81 01 22	0.02 L	80 03 13	0.03
				80 07 07	0.02 L	80 06 10	0.02 L	81 02 16	0.02 L	80 06 10	0.02 L
				80 08 11	0.02 L	80 07 08	0.02 L	81 03 16	0.02 L	80 07 08	0.02 L
				80 09 09	0.02 L	80 08 13	0.02	81 06 02	0.02 L	80 08 13	0.02 L
				81 01 20	0.02 L	81 09 10	0.02 L	81 07 30	0.02 L	80 09 10	0.02 L
				81 03 18	0.02 L	81 01 22	0.02 L	81 10 05	0.02 L	81 01 22	0.02 L
				81 06 04	0.02 L	81 02 16	0.02 L	82 01 11	0.02 L	81 02 16	0.02 L
				81 07 28	0.02 L	81 03 16	0.02 L	82 03 08	0.02 L	81 03 16	0.02 L
				81 10 08	0.02 L	81 06 02	0.02 L	82 06 08	0.02 L	81 06 02	0.02 L
				82 01 13	0.02 L	81 07 30	0.02 L	82 07 07	0.02 L	81 07 30	0.02 L
				82 02 10	0.07	81 10 05	0.02 L	82 08 16	0.02 L	81 10 05	0.02 L
				82 06 09	0.02 L	82 02 08	0.02 L	83 07 04	0.02 L	82 01 11	0.02 L
				82 07 06	0.02 L	82 03 08	0.04	83 08 22	0.02 L	82 02 08	0.11
				82 08 17	0.02 L	82 06 08	0.02 L	83 09 22	0.02 L	82 03 08	0.02 L
				83 07 05	0.02 L	82 07 07	0.02 L	84 01 10	0.02 L	82 06 08	0.02 L
				83 08 23	0.02 L	82 08 16	0.02 L	84 02 08	0.02 L	82 07 07	0.02 L
				83 09 19	0.02 L	83 07 04	0.02 L	84 03 05	0.02 L	82 08 16	0.02 L
				84 02 09	0.02 L	83 08 22	0.02 L			83 07 04	0.02 L
				84 03 06	0.02 L	83 09 22	0.02 L			83 08 22	0.02 L
						84 01 10	0.02 L			83 09 22	0.02 L
						84 02 08	0.02 L			84 01 10	0.02 L
						84 03 05	0.02 L			84 02 08	0.02 L
										84 03 05	0.02 L

detected were reported as 0.02 µg/L, with 0.07 µg/L being observed on a single occasion.

Because most of the detectable concentrations were observed on a single sampling excursion, it would appear likely that such values resulted from either a systematic sampling or analytical bias. Other extractable mercury values may have similarly been influenced. Experience with the collection and analyses of water samples for extractable mercury content has shown that, due to the persistent and ubiquitous nature of mercury in uncontrolled field surroundings, sample contamination may sometimes occur. Conversely however, extractable mercury has been detected in water at concentrations near 0.02 µg/L downstream of anthropogenic activities such as metal mining and smelting operations. Hence, it is possible that the observed positive detection of extractable mercury concentrations in water were real and represented the upper percentiles of the normal distribution of mercury.

Water samples, collected from three sites located on the upper Nelson River namely, Little Playgreen Lake near Norway House, Cross Lake near the community of Cross Lake and near the outlet of Sipiwesk Lake, were analyzed for extractable mercury.

Most observations were below the limit of quantitation (0.02 µg/L). However, concentrations at or above this limit, ranging from 0.02 µg/L to 0.11 µg/L, were reported from several locations at infrequent sampling intervals. The highest concentration detected, namely 0.11 µg/L, was observed at Sipiwesk Lake in February, 1982. Mercury was also detected in samples collected two days later from Split Lake. Such detected extractable mercury

concentrations likely occurred for reasons similar to those discussed previously with regard to detected extractable mercury concentrations within areas affected by the Churchill River diversion.

Mercury in Sediments

Total mercury data in lake and river surficial bottom sediments are presented in Table 3. The predominant physical characteristics of the sediment samples were observed during sample collection and are summarized in Table 4. Mercury in surficial bottom sediment monitoring sites were co-located with mercury in water sampling sites (Figure 1; Table 1).

Mercury concentrations in surficial bottom sediments collected from areas affected by impoundment and diversion projects on the Churchill River system were variable. All concentrations were found to be within the range of "naturally-occurring" mercury in bed sediments as summarized by Williamson (1980).

Mercury concentrations in surficial bottom sediments were regressed with time in order to determine whether the observed changes in such concentrations throughout the duration of the investigation were linearly related with time. This procedure however, was confounded by the large number of data qualified with less than quantitation designations. Two methods were used to assist the interpretation of these data. Firstly, the numerical values recorded in Table 3 were entered into the regression analyses without consideration of the qualifying designations. The qualifying designations were then used to assist in subjectively assessing the validity of the regression analyses. This method resulted in the

Table 3: Total mercury content of river and lake surficial bottom sediments. Results are expressed as µg/g, dry weight equivalent.

	LOCATION	1979	1980	1981	1982	1983
WQ 385	Churchill River upstream of Granville Lake	<0.02*	0.02	<0.04	<0.03	<0.03
		0.02	0.03	0.03	-	<0.04
		0.02	0.03	<0.03	-	<0.04
WQ 389	Barrington River upstream of Opachuanau Lake	0.07	0.06	0.07	<0.05	<0.06
		0.06	0.07	0.07	-	<0.05
		0.07	0.09	<0.04	-	0.05
WQ 051	Southern Indian Lake near South Indian Lake Community	0.05	0.04	<0.03	<0.04	<0.04
		0.05	0.05	<0.04	-	<0.04
		0.04	0.06	<0.04	-	<0.04
WQ 050	Footprint Lake near Nelson House Community	0.08	0.07	0.06	<0.03	<0.04
		0.08	0.09	0.06	-	<0.04
		0.08	0.07	<0.04	-	<0.03
WQ 093	Burntwood River at Thompson	0.02	-	<0.03	<0.03	<0.03
		-	-	<0.03	-	<0.03
		-	-	<0.03	-	<0.03
WQ 422	Burntwood River at Apussigamasi Lake	0.04	0.04	<0.03	<0.04	<0.03
		0.04	0.03	<0.03	-	<0.03
		0.04	0.04	<0.03	-	<0.03
WQ 047	Split Lake near Split Lake Community	0.03	0.04	<0.03	<0.04	<0.04
		0.04	0.04	<0.03	-	<0.04
		0.04	0.05	<0.03	-	<0.04
WQ 049	Nelson River at Norway House Community	0.03	0.03	0.03	0.06	<0.06
		0.04	0.04	0.05	-	<0.07
		0.03	0.04	0.05	-	<0.05
WQ 442	Cross Lake near Cross Lake Settlement	0.04	0.05	<0.03	0.06	<0.09
		0.04	0.04	0.06	-	<0.04
		0.04	0.04	0.03	-	<0.04
WQ 048	Sipiwesk Lake near outlet	-	0.02	<0.03	<0.03	<0.04
		-	0.03	<0.03	-	<0.04
		-	0.03	<0.03	-	<0.04

* Please note: While the wet weight analytical limit of quantitation was 0.02 µg/g, conversion to dry weight equivalent basis by consideration of individual sample moisture content resulted in the various reported limits of quantitation.

Table 4: Physical characteristics of river and lake surficial bottom sediment samples.

	Location	Characteristics
WQ 385	Churchill River upstream of Granville Lake	Fine mineral sediment; some sand and gravel present; evidence of recent deposition (stratification).
WQ 389	Barrington River upstream of Opachuanau	Fine mineral-organic sediment; evidence of recent deposition (stratification).
WQ 051	Southern Indian Lake near South Indian Lake Community	Fine mineral-sediment; evidence of recent deposition (1 cm of fine clay).
WQ 050	Footprint Lake near Nelson House Community	Fine mineral sediment; evidence of recent deposition (stratification).
WQ 093	Burntwood River at Thompson	Fine mineral sediment; presence of sand; some organic material present.
WQ 422	Burntwood River at Apussigamasi Lake	Fine mineral sediment; evidence of recent deposition (stratification).
WQ 047	Split Lake near Split Lake Community	Fine mineral sediment; evidence of recent deposition (stratification).
WQ 049	Nelson River at Norway House Community	Fine mineral sediment; evidence of recent deposition (stratification).
WQ 442	Cross Lake near Cross Lake Settlement	Fine mineral-organic sediment; evidence of recent deposition (stratification).
WQ 048	Sipiwesk Lake near Outlet	Fine mineral sediment; evidence of recent deposition (stratification).

identification of a statistically significant decreasing linear trend with time at Footprint Lake near the community of Nelson House ($r^2 = 0.86$, slope = - 0.013, $\rho \neq 0$, $\alpha = 0.05$). This procedure however, may have artificially reduced the variability of the data, thus resulting in a spurious trend (Type I statistical error).

Secondly, random values less than the qualified concentrations were substituted into the statistical regression analysis in place of the qualified concentrations. The decreasing linear trend with time at Footprint Lake near the community of Nelson House was no longer statistically significant ($\alpha = 0.05$) with this method. This latter method however, may have conversely artificially increased the variability of the data, resulting in the absence of a trend when one may have existed (Type II statistical error).

Analyses of variance and Duncan's Multiple Range tests were used to determine whether differences in total mercury content of surficial bottom sediments existed between sampling locations. The data qualified by less than quantitation designations were treated in a similar manner as previously described with regard to the regression analyses. Numerous statistically significant differences between sites were identified when the qualifying designations were omitted. However, when the analyses were repeated with substituted random variables less than the limit of quantitation, statistical significance was lost.

In summary, uncertainties with rigorous data analysis precludes the identification of differences in total mercury concentrations in surficial bottom sediments with time or between sampling sites with confidence. In any case, the range of total

mercury concentrations in surficial bottom sediments within replicates on each sampling occasion, between sampling occasions at each sampling site and between sampling sites included in the investigation was found to be relatively small (<0.02 µg/g to 0.09 µg/g) and near the technical limit of quantitation.

Conclusions

It was concluded that:

(1) Extractable mercury concentrations in water, with limited exceptions, were below the analytical limit of quantitation.

(2) The limited number of extractable mercury concentrations in water observed above the analytical limit of quantitation may have resulted either from systematic or non-systematic analytical or sampling bias or may represent the upper several percentiles of the normal extractable mercury distribution.

(3) Total mercury concentrations in surficial bottom sediments displayed little apparent change at all sampling sites throughout the duration of the investigation.

(4) Little apparent difference was evident between total mercury concentrations in surficial bottom sediments measured at the various sampling sites.

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